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On the Determination of Longitude on the Planet Jupiter.

By G. W. Hough.

I have read with some astonishment the paper by Mr. A. S. Williams in the *Monthly Notices* for March 1904 on the determination of longitude on the planet *Jupiter.* It is difficult to believe that he was in earnest in his presentation of the subject. As an illustration of the kind of logic employed, in paragraph 15 he asserts that in a micrometer measure of the central meridian there are four sources of error, in the observation of a transit only one source of error; hence the latter is the more accurate method. In other words, one can guess the centre of the disc better than one can measure it.

The table of so-called data consists almost entirely of the comparison of five or six observations *inter se,* selecting such as show a small mean residual. About one-third of the data cited has a mean residual of $+1^{\mathrm{m}}{\cdot}0$ or less, a purely imaginary value. One minute of rotation time means $0''{\cdot}17$ of arc. The table of data is open to just criticism, but I shall simply call attention to a few grave errors.

Schmidt, Red Spot 1879–87, carried a mean error $\pm 3^{\mathrm{m}}{\cdot}0$, corrected observations $\pm 1^{\mathrm{m}}{\cdot}9$, *not* $\pm 1^{\mathrm{m}}{\cdot}5$. Barnard, Red Spot 1880–2, carried a mean error $\pm 4^{\mathrm{m}}$, *not* $\pm 0^{\mathrm{m}}{\cdot}7$. Barnard, Red Spot 1891, the residual $\pm 0^{\mathrm{m}}{\cdot}8$ was derived from a comparison with Marth's Ephemeris, which did not represent the motion; the true mean residual is $\pm 1^{\mathrm{m}}{\cdot}8$. Williams, Red Spot 1899, carries a mean residual $\pm 2^{\mathrm{m}}{\cdot}3$, *not* $\pm 3^{\mathrm{m}}{\cdot}1$. Williams, Red Spot 1900, carries a mean residual $\pm 2^{\mathrm{m}}{\cdot}8$, *not* $\pm 0^{\mathrm{m}}{\cdot}8$. Jedrzejewicz, Red Spot 1880–1; these observations were made with the help of a micrometer, and according to the observer's own statement should carry a mean residual $\pm 2^{\mathrm{m}}{\cdot}2$. The residual $\pm 0^{\mathrm{m}}{\cdot}5$ is fictitious. Spots giving the short rotation period are not used at all.

From such a "discussion" he gets the following:

Mean error: Micrometer, $\pm 2^{\mathrm{m}}{\cdot}0$.
„ Eye estimates, $\pm 1^{\mathrm{m}}{\cdot}7$.

Hence the following logical conclusions:

1. A single eye estimate is decidedly superior in point of accuracy to micrometer measures.

2. One can bisect the disc of the planet by a single estimation with an average error of $0''{\cdot}27$ of arc, and under favourable conditions to $0''{\cdot}10$ arc. It is unnecessary to make any extended comments on such data and the inferences that may be drawn from them, but rather to add something to our knowledge of the magnitude of error in micrometer and eye-estimate work. Hitherto we have had speculation and conjecture rather than investigation regarding the limit of error in eye estimates.

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Schmidt, from a discussion of all his observations on the Red Spot, 1879 to 1881, found a variable error amounting in the maximum to 8 minutes, which he thought was dependent on the hour angle of the planet. He also compared the observations made by twenty other observers, and found a range of 9 minutes in the mean personal equation. These facts were apparently established, but the causes were somewhat obscure. Schmidt thought the variable error might be due to the inclination of the belts as seen by the observer; but from his remarks on the uncertainty of the date it appears that he was not certain that this was the true explanation. It has occurred to me that it might be due to an optical illusion with which every one is familiar. If we look at the figure 8 inverted the two parts are no longer symmetrical. Now, if such variable error really exists, any discussion which aims to determine the magnitude of error is absolutely worthless if this phase of the subject is ignored.

Mr. Williams, without investigation, asserts that a variable error as indicated by Schmidt is not found in the work of other observers, "most of whom, it is believed, take the precaution of keeping the eyes parallel to the belts when observing the transits." It would appear from the above statement that Mr. Williams has never examined his own observations.

Lohse, *Potsdam Pub.* No. 9, found from his own observations mean errors $\pm 2^{\mathrm{m}}{\cdot}0$ to $\pm 6^{\mathrm{m}}{\cdot}0$. Hall, observations of *Saturn*, found a mean error $\pm 3^{\mathrm{m}}{\cdot}0$. All these results are from the comparison of observations *inter se*, and do not necessarily represent the true error. Barnard, without any investigation, *thought* some of his observations would have a mean error $\pm 0^{\mathrm{m}}{\cdot}7$. The mean error was about $\pm 4^{\mathrm{m}}$. Some years ago I showed that the small residual $\pm 0^{\mathrm{m}}{\cdot}7$ imagined by Barnard was a mistake, but Mr. Williams has not hesitated to incorporate it in his list of data.

Schmidt, *Ast. Nach.* 2410, gives the following for the Red Spot, 1879–81 :

	Reduced without Weight. m	Empirical Corrections applied. m	
Mean error ...	± 3·00	± 1·90	97 obs.
Probable error ...	± 2·02	± 1·28	

Mr. Williams, by a strange oversight, has assigned to these observations a mean error $\pm 1^{\mathrm{m}}{\cdot}5$. Then with this fictitious value annexed he brings them forward in proof of the accuracy of eye estimates. If Schmidt's corrections were valid, which is extremely doubtful, as will be seen later, the corrected observations can no longer be regarded as eye estimates and have no place in his discussion.

It seems to me that Mr. Williams is on the horns of a dilemma with regard to Schmidt. If he admits the validity of a variable error, it requires no argument to show the untrustworthy nature of eye estimates. If, on the contrary, he denies the existence of such error, he must accept a mean residual error $\pm 3^{\mathrm{m}}\cdot 0$.

If a variable error of the magnitude assumed by Schmidt really exists in eye-estimate observations, it will seriously impair the value of the rotation period deduced. I have spent considerable time to ascertain :

1st. The magnitude of such variable error, if any.

2nd. Whether it is the same for all observers.

3rd. Whether it depends on the hour angle of the planet.

In order to accomplish this I have compared a few sets of observations by well-known observers, covering a considerable time interval, with my micrometer work for the same period.

Before making such comparison we should ascertain the amount of accidental and personal equation error in micrometer work. I have shown elsewhere that one set of measures under fair atmospheric conditions will give the time of passage over the central meridian within one minute. When the observations cover a considerable interval of time, including good and bad seeing, and are compared with an ephemeris, the mean residual (O—E) is about $\pm 1^{\mathrm{m}}\cdot 5$, as may be ascertained by an examination of the work published in the *Monthly Notices* and *Ast. Nach.* The personal equation is assumed to be practically zero, for the following reasons :

1st. Measures of a spot on the same night on both sides of the central meridian indicate no constant difference.

2nd. Observations of the Red Spot during oppositions when it was nearly stationary show no irregularity in the residuals when compared with Marth's ephemeris. During the opposition a spot is measured about an equal number of times on either side of the central meridian, and hence there can be no cumulative error.

That we may clearly see the nature of the errors incident to eye estimates I have given in detail the observations made by Denning and Williams in 1887, together with my micrometer work covering the same opposition. My observations are given in standard mean time 6 hours slow of Greenwich. The others may be found in the volume *Zenographical Fragments*, by A. Stanley Williams, p. 96. The observations were compared directly with Marth's Ephemeris. I have chosen this set for the following reasons :

1st. They are the work of recognised observers.

2nd. They cover the whole opposition.

3rd. The ephemeris is by Marth, and represents the rotation period very closely. This is now known to be true by comparing it with the rotation periods of the preceding and following oppositions. I am particular in giving this detail, since the comparison of my observations shows clearly that there is no variable personal equation in micrometer measures. On 1887 July 19 and 22 the longitude measures were made respectively 63^{m} east and 41^{m} west of the central meridian of the disc.

The longitude differences are almost identical, a good proof that the personal equation was zero.

These observations are a fair average of the kind of work done by all observers when the time interval is considerable. The table is worthy of serious study by any one who imagines the eye-estimate method is capable of yielding results of precision, such as are demanded in other lines of astronomical work.

Hough.

1887.		T.	Long.	O−E.
		h m	m	m
Jan.	28	18 02·3	− 9·3	−1·3
Mar.	8	15 14·9	− 6·3	+1·7
Apr.	7	9 54·0	− 9·8	−1·8
	24	8 56·4	− 6·3	+1·7
	29	8 00·7	− 9·2	−1·2
May	13	9 31·0	− 9·9	−1·9
	18	8 46·6	− 1·8	+6·2
	28	6 57·1	− 7·1	+0·9
June	8	11 00·4	− 7·2	+0·8
	11	8 29·1	− 8 3	−0·3
	13	10 09·1	− 6 9	+1·1
	16	7 38·7	− 7·3	+0·7
	23	8 23·6	− 9·7	−1·7
	25	10 02·9	− 8·2	−0·2
	28	7 29·9	−12·2	−4·2
July	7	10 00·7	− 7·9	+0·1
	12	9 11·3	− 6·5	+1·5
	19	9 55·5	−10·5	−2·5
	22	7 25·7	−10·9	−2·9
	29	8 13·9	− 6·0	+2·0
Mean Long.			− 8·0	±1·7

Denning-Williams.

1886.		Long.	O−E.	Actual Error.
		m	m	m
Nov.	23	− 2·5 D.	+ 9·0	+ 5·5
Dec.	17	− 4·9 D.	+ 6·6	+ 3·1
	20	−11·0 W.	+ 0·5	− 3·0
1887.				
Jan.	1	− 6·0 „	+ 5·5	+ 2·0
Feb.	26	− 4·8 „	+ 6·7	+ 3·2
Mar.	20	− 3·9 „	+ 7·6	+ 4·1
	27	− 6·9 „	+ 4·6	+ 1·1
	29	−15·8 „	− 4·3	− 7·8
Apr.	3	− 9·9 „	+ 1·6	− 1·9
	10	−21·8 „	−10·3	−13·8
	17	−12·7 „	− 1·2	− 4·7
	20	−13·8 „	− 2·3	− 5·8
	24	−15·2 „	− 3·7	− 7·2
	27	−14·9 „	− 3·4	− 6·9
	29	−17·9 „	− 6·4	− 9·9
May	2	−15·6 „	− 4·1	− 7·6
	7	−15·5 D.	− 4·0	− 7·5
	9	−15·5 W.D.	− 4·0	− 7·5
	10	−13·8 D.	− 2·3	− 5·8
	14	−15·1 W.	− 3·6	− 7·1
	26	−14·8 D.	− 3·3	− 6·8
June	10	−11·3 D.	+ 0·2	− 3·3
	19	−21·0 W.	− 9·5	−13·0
	22	− 6·1 D.	+ 5·4	+ 1·9
July	16	− 5·8 D.	+ 5·7	+ 2·2
Aug.	6	− 4·2 D.	+ 7·3	+ 3·8
Mean Long.		−11·5	± 4·7	± 5·6

The column "Long." is the longitude in time from Marth's Meridian II. The column "Actual Error" is the difference between the observed longitude and the true longitude resulting from the micrometer measures. The residuals O—E, for both micrometer

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and eye estimates, represent the accidental error of observation without regard to any personal equation. For this set the mean residual O − E was, for the micrometer $\pm 1^{m}{\cdot}7$, for eye estimates $\pm 4^{m}{\cdot}7$. The actual mean error for eye estimates was $\pm 5^{m}{\cdot}6$. The combined personal equation for Denning and Williams was $-3^{m}{\cdot}5$. When the observations of the two observers are treated separately we find for the mean personal equations :

	m
Denning	−1·4
Williams	−4·4

An inspection of the column of longitudes shows very clearly a variable error which amounted to about ten minutes, but it did not vary in the same way for both observers. Denning obtained the same longitude differences at the beginning and end of the series, but changed his longitude about ten minutes in the middle. Williams on the other hand began with nearly the same longitude as Denning, but suddenly about April 1 changed about ten minutes and continued pretty steadily on the new longitude to the end of the series. These observations do not show any direct connection between the hour angle of the planet and the variable error, as had been assumed by Schmidt.

Mr. Williams remarks : "The mean rotation period, November 1886 to May 1887, was $9^{h}\ 55^{m}\ 38^{s}{\cdot}8$; May to August, $9^{h}\ 55^{m}\ 44^{s}{\cdot}0$. Making use of observations near the beginning and end of the series, the mean period is $9^{h}\ 55^{m}\ 40^{s}{\cdot}51$." He also says the irregularities in the motion may be due to the different positions of the planet before and after opposition.

Messrs. Denning and Williams are experienced observers and do as good work as can be done by the method used. Yet it is readily seen how erroneous may be the conclusions drawn from such observations. Here we have apparently a well-established fluctuation in the rotation period of 5·2 seconds which did not exist. The residuals for the micrometer observations show that the rotation period was sensibly stationary, and was practically the same as that used for the ephemeris, viz. $9^{h}\ 55^{m}\ 40^{s}{\cdot}63$.

Now having clearly shown that the micrometer is free from cumulative error due to a variable personal equation, we may examine a few sets of observations by other well-known observers. The following table indicates some of the results. To give the observations in detail would consume too much space. It may be said, however, that persistence in error in one direction, in some cases, is even more apparent than in the example already given.

Object.		Time Interval. Days.	No. Obs.	O − E.	Mean Personal Equation.	Observer.
				m	m	
Red Spot 1891	...	242	23	± 1 7	...	Ho.
,,	...	122	11	± 1·8	−5·8	Barnard
Long Red 1891	...	117	12	± 2·0	...	Ho.

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Object.	Time Interval. Days.	No. Obs.	O−E.	Mean Personal Equation.	Observer.
			m	m	
Long Red 1891 ...	85	13	±1·7	−2·5	Barnard
Small Black 1891 (*a*)	119	10	±1·5	...	Ho.
„ (*a*)	92	7	±5·3	−5·8	Barnard
„ (*b*)	85	13	±4·2	0	Barnard
Red Spot 1899 ...	225	27	±1·6	...	Ho.
„ ...	95	9	±2·3	−7·7	Williams
Red Spot 1900 ...	199	17	±1·3	...	Ho.
„ ...	113	4	±2·8	−7·3	Williams
Black Spot 1898 ...	191	18	±2·2	...	Ho.
„ ...	144	24	±4·1	−2·4	Gledhill
Red Spot 1887 ...	182	20	±1·7	...	Ho.
„ ...	252	10	±4·7	−1·4	Denning
„ ...	181	17	±4·9	−4·4	Williams

The variable personal equation was :

Barnard ...	Red Spot	Beginning -2^{m}	End -7^{m}
„ ...	Long Red	Not well indicated	
„ ...	Small Black (*a*)	Beginning -15^{m}	„ 0
„ ...	„ (*b*)	„ -4^{m}	„ $+3^{m}$
Williams...	Red Spot 1899	Not well indicated	
„ ...	„ 1900	Beginning −3	„ +3
Gledhill ...	Black Spot 1898	„ −4	„ +6
Denning ...	Red Spot 1887	Beginning and end +4	Middle −5
Williams...	„ „	Beginning +3	Middle and end −7

The numbers indicating variable personal equation are the average of a number of contiguous observations, and are necessarily approximate.

The spots *a* and *b* observed by Barnard in 1891 present a curious phase in eye-estimate observations. Barnard observed both spots on the same night at the beginning and end of the series. The other observations alternate on different nights. The two spots were in the same latitude and in close proximity, the difference of longitude by the micrometer being $24^{m}{\cdot}8 \pm 0^{m}{\cdot}6$. Barnard's observations give $30^{m}{\cdot}8 \pm 0^{m}{\cdot}9$, or a constant error of six minutes in the distance between them. The mean personal equation, as already given, indicates the same constant error. In other words, his central meridian differed $5^{m}{\cdot}8$ for the two spots.

The following inferences may be drawn from the above data :

1st. In all cases the "mean" personal equation was negative,

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which means that observations on the average were made too soon, or before the spot reached the central meridian.

2nd. There is apparently no real personal equation as the term is understood in precision observations. In eye-estimate observations the term personal equation, which I use for convenience, seems to be made up of accidental error taken in connection with the peculiar method employed in making the observations. It is easily understood why an observer may record five minutes too soon on one night and five minutes too late on the next night, but why we should persist in recording ten minutes too soon or too late over a long interval I am unable to explain.

3rd. The mean residual O—E from a comparison with the ephemeris is more than twice as great as for the micrometer, some observations of the Red Spot excepted.

4th. These residuals represent the average accidental error of observation, not including the mean personal equation.

5th. The real error at any point is the algebraic sum of the residual and the mean personal equation.

6th. The "mean" personal equation is not the same for the different spots observed.

7th. The personal equation is not constant, but may change so much during the opposition as to greatly impair the value of the rotation period.

8th. The number for variable personal equation taken in connection with the mean residual indicates that an observer may be persistently in error ten to fifteen minutes in determining the time of passage of a spot over the central meridian of the disc. This conclusion is confirmed by a great number of observations published during the past twenty-five years (vide *Monthly Notices*, "Comparison of observations by Marth and others").

The observations mentioned above do not show any law connecting the variable error with the hour angle of the planet. I think it highly probable that Schmidt's explanation was erroneous.

The accidental error in eye estimates is not nearly so serious a defect as the variable error. If the observer at the end of one hundred days observes fifteen minutes earlier or later than at the beginning, the rotation period deduced will be considerably in error.

The variable persistent error is undoubtedly responsible for the erroneous deductions regarding the motion of the Red Spot and other spots which have been published frequently at different times in past years. A favourite way to account for discordant observations is to assume irregular motion in the spot. Although the motion of no spot on *Jupiter* can be regarded as constant for a long interval yet there is never any abrupt change in its drift, as indicated by my observations for the past twenty-five years. When the time interval is less than one hundred days the observations usually can be fairly satisfied

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by assuming a uniform rotation period. Occasionally, however, it is necessary to use a variable rotation period to bring the residuals within the probable errors of observation. Examples of this kind may be found in *Monthly Notices*, lii. 412, and *Ast. Nach.* 3354.

The personal equation problem is one of so much importance that I have made a few additional comparisons, to ascertain its amount in different years. For convenience of reference all the data are arranged in the following table :

Denning.

		Mean Pers. Eq.	Variable.
		m	m
Red Spot	1880	−4·6	6
,, ...	1883	−7·7	6
,, ...	1885	−3·2	
,, ...	1887	−1·4	6
,, ...	1901	−2·5	
White Spot	1881	0	3

Williams.

		m	m
Red Spot	1887	−4·4	10
,, ...	1899	−7·7	
,, ...	1900	−7·3	5
,, ...	1902	−2·9	6
White Spot	1881	+0·8	7
Spot (*a*)	1898	−5·9	3

Schmidt.

		m	m
Red Spot	1880 Sept.	−8·3	±0·7
,, ...	Nov.	−0·6	±1·5
,, ...	1881 Jan.	−4·0	±1·0

Denning, 1880.—The personal equation was derived from five consecutive observations at two dates, October 11 and December 20, giving respectively $-7^{m}{\cdot}7$ and $-1^{m}{\cdot}5$ with a probable mean error less than $\pm 1^{m}$.

Schmidt's observations were treated in the same manner for the dates given. It is readily seen that there is no constancy in the mean personal equation from year to year.

During the opposition the variation is usually in one direction only. In view of the difficulty in making an observation it is possible that these abnormal results are simply due to accidental error.

As an illustration of the uncertainty involved in eye estimates

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I refer to one of Barnard's observations of a white spot on *Saturn* (*Astronomical Journal*, No. 547).

	h	m	
1903 August 2	13	46	Very nearly in transit.
		49	Perhaps not yet in transit.
		52	In transit.
		56	„ „
		58	Perhaps in transit.
	14	00	Perhaps past; a little uncertain.
		02	„ „ „ „
		08	Past, but not decidedly so.
		14	Decidedly past transit.

The time adopted was 13^{h} 57^{m}, which is five minutes later than the first recorded transit. From the data given I should adopt 13·54 as the most probable value.

In this example, for an interval of nineteen minutes, a space equal to 1″·6 of arc, the observer was uncertain whether the spot was on the central meridian or not. And for an interval of six minutes, or a space of 0″·5 arc, he was sure it was on the central meridian. On the planet *Jupiter*, on account of the greater size of the disc, the uncertainty in the time of transit would be about one-half as great as for *Saturn*. Mr. Williams and other observers do not seem to understand the nature of the problem involved in eye estimates or transits, viz. the space in seconds of arc that the eye can discriminate.

I can say with certainty that no spot on *Jupiter* of 0″·5 in diameter has ever been observed for rotation time, and probably none less than 1″ of arc. At mean distance 1″ of arc on *Jupiter* corresponds to 5·5 minutes of rotation time.

Adopting the space values as given for *Saturn* there would be an interval of 9 minutes during which the observer might be in doubt regarding the transit, and an interval of 2·8 minutes when he was sure the spot was in transit.

The absurdity of the claim for a mean error $\pm 1^{m}\cdot 0$ or 0″·2 of arc is apparent.

It is a curious anomaly, however, that the Red Spot, the most difficult object on the disc of late years, when the rotation period was nearly stationary, has apparently furnished this small residual error, while other spots, for which there was no ephemeris, but were capable of much more accurate determination, in the majority of cases yield a mean error ±3 to ±5 minutes.

Mean Error.

Mr. Williams in his extended remarks on error does not seem to apprehend the difference between mean or probable error and constant error. Without discussing the question I may say

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that the errors derived in my report, 1882, were determined in the usual way and are correct. The residuals when observations are compared with an ephemeris are made up of mean error, constant error, and variable motion.

In *Monthly Notices*, lii. 412, for the Red Spot the mean residual for uniform motion was $\pm 1^{\rm m}{\cdot}7$, for variable motion $\pm 1^{\rm m}{\cdot}2$. In my report for 1882 the observations of the Red Spot from 1879 September 25 to 1882 March 29, a period of 916 days, are compared with an ephemeris in which the rotation period increased with the time. Mr. Williams, perhaps inadvertently, stated that Schmidt's observations from 1879 November 10 to 1881 March 20 gave a mean error of $\pm 1^{\rm m}{\cdot}5$, "exactly the same as mine." Schmidt's mean error was $\pm 3^{\rm m}{\cdot}0$.

Identification of Spots.

I am at a loss to know what Mr. Williams requires for the identification of a spot on *Jupiter*. Here are four observations which he says belong to three different spots :

Days.	O−E. m	App. Lat. ″
0	+0·0	−0·93
37	+3·3	...
78	+0·8	−1·74
80	+0·1	−1·61

This spot is identified both by latitude and longitude. The longitudes are represented by a mean error of $\pm 1^{\rm m}{\cdot}0$, and the latitudes are well within the limit of error, the first observation differing only $0''{\cdot}50$ from the mean. I venture to say that neither Mr. Williams nor anybody else has ever made a more certain identification.

Three observations of a spot at unequal intervals of time are sufficient to definitely fix the rotation period. The spots I observe are generally identified by both longitude and latitude, whereas in eye estimates one must rely on longitude only.

Mr. Williams remarks that about 40,000 transits have been observed, "and that these constitute the foundation of much of our knowledge of the rotation of *Jupiter* and the various surface currents known to exist," &c. He has also remarked on another occasion that eye estimates could accomplish all that can be done with the micrometer. I have grave doubts regarding both statements. I have repeatedly urged that the element of latitude is of equal value with that of longitude in arriving at a knowledge of the conditions of the surface of the planet.

The foregoing discussion proves conclusively the existence of a variable error, even beyond the limits assigned by Schmidt. All the observers, in the examples cited, without exception, either gradually or suddenly changed the zero of reference in

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some cases 10 minutes or more. Such an error corresponds to about 2″ of arc on the disc of *Jupiter*. It also shows that the ordinary accidental error is fully as large as has been stated by others, viz. 3 to 5 minutes. Hence I infer that for a short time interval, viz. 30 days or less, the method is absolutely worthless in so far as securing a trustworthy rotation period is concerned.

On the contrary, when the time interval is more than 200 days the combination of the work of a number of observers may yield a fair mean rotation period, but in no case is it capable of disclosing a variable rotation period, or, in other words, representing the true motion of the spot or marking. The method of eye estimates was used before modern instruments of precision were known. It was then the only method available. I think now no astronomer who has the necessary apparatus would employ it if he fully understood the uncertainty of the results.

References.

The Red Spot, 1880	Hough	*Report Chicago A. S.* 1882
,, ,,	Denning	*M. N.* xli. 358
,, ,,	Schmidt	*A. N.* 2410
,, 1883	Denning	*M. N.* xliv. 64
,, 1885	,,	,, xlvi. 117
,, 1901	,,	*Observatory*, xxiv. 313
,, 1899	Williams	*A. N.* 3596
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Black Spot *a*, 1898	,,	,, lx. 552
,, ,, ,,	Gledhill	,, lviii. 500
,, ,, ,,	Williams	*Observatory*, xxi. 341
White Spot, 1881	,,	*M. N.* xlii. 428
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,, ,,	Hough	*Report Chicago A. S.* 1882

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Observations of the Satellite of Neptune from Photographs taken at the Royal Observatory, Greenwich, between 1903 *December* 4 *and* 1904 *April* 18.

(*Communicated by the Astronomer Royal.*)

The following measures of position angle and distance of *Neptune's* satellite were made from photographs taken with the 26-inch refractor of the Thompson equatorial. The occulting shutter was used, as in previous years, the photographs being taken by Messrs. Davidson, Edney, or Melotte. The photographs were measured in a position micrometer in direct and reversed positions by Mr. Dyson and Mr. Edney. The tabular positions with which comparison is made were computed from the data given in the *Connaissance des Temps*, based on Dr. H. Struve's elements, the eccentricity of the orbit being neglected on account of the uncertainty in the present position of peri-astron. For fuller particulars as to the photographs and their measurement reference may be made to a previous paper in the *Monthly Notices*, vol. lxii. pp. 622–626.

NEPTUNE AND SATELLITE.

Position Angle and Distance, from Photographs taken with the 26-inch Refractor.

Date and G.M.T.					Position Angle.			Distance.			Remarks.
					Observed.	Tabular.	T−O.	Observed.	Tabular.	T−O.	
1903.	d	h	m	s	°	°	°	″	″	″	
Dec.	4	11	20	34	97·25	97·70	+0·45	16·46	16·56	+0·10	
	8	12	32	26	225·60	226·72	+1·12	13·28	13·40	+ ·12	
	9	11	25	46	145·03	146·41	+1·38	12·32	11·98	− ·34	
	9	12	10	35	142·94	143·97	+1·03	12·11	12·15	+ ·04	
	10	11	8	18	91·03	92·95	+1·92	16·76	16·80	+ ·04	
	10	11	47	50	91·53	91·86	+0·33	17·02	16·81	− ·21	
	14	10	43	25	223·17	223·66	+0·49	13·03	13·13	+ ·10	
	15	11	40	23	135·15	136·47	+1·32	12·68	12·72	+ ·04	
	17	10	26	21	40·08	40·32	+0·24	13·05	12·84	− ·21	
	30	11	14	11	297·34	298·44	+1·10	14·36	14·49	+ ·13	
	30	11	51	15	296·50	297·11	+0·61	14·54	14·62	+ ·08	
	31	11	11	28	254·55	255·18	+0·63	16·71	16·44	− ·27	Definition very poor.
	31	11	42	41	252·84	254·26	+1·42	16·28	16·37	+ ·09	Definition very poor.
1904. Jan.	6	10	55	54	249·35	250·28	+0·93	15·83	16·04	+ ·21	
	13	9	1	24	177·16	179·21	+2·05	11·15	11·00	− ·15	
	13	9	33	25	176·68	177·04	+0·36	11·10	10·99	− ·11	
	14	10	4	22	105·00	105·53	+0·53	16·09	15·79	− ·30	
	14	10	39	39	103·04	104·42	+1·38	15·98	15·90	− ·08	
	15	10	0	32	62·79	63·48	+0·69	15·25	15·34	+ ·09	